Round-Robin Study of Arsenic Implant Dose Measurement in Silicon by Secondary Ion Mass Spectrometry (SIMS)

The purpose of this international round robin study was to determine the best analytical conditions and the level of interlaboratory agreement for the determination of the implantation dose of arsenic in silicon by SIMS. Motivations for this study were: (a) the relatively poor interlaboratory agreement that was observed in a previous round-robin study before a certified reference material had become available; (b) the previous observation that the use of Si_3^- as a matrix species combined with $AsSi^-$ detection may result in improved measurement repeatability compared with the use of Si_2^- as a matrix species; and (c) the previous observation that point-by-point normalization of the arsenic signal to the matrix signal can extend the linearity of SIMS response for arsenic in silicon beyond $1x10^{16}/cm^2$.

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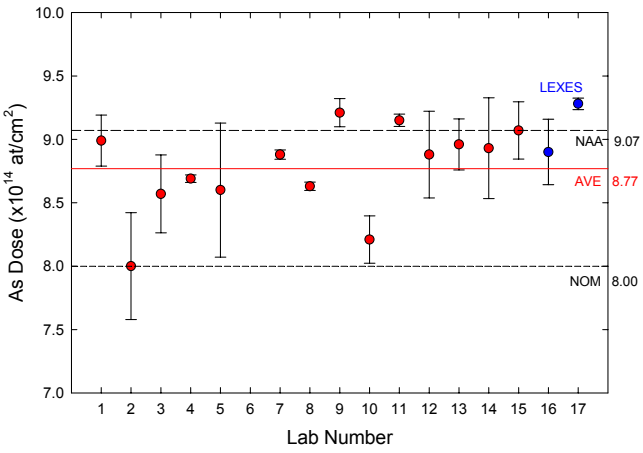
Fifteen SIMS laboratories from six countries participated in this study, as well as two laboratories that performed low energy electron-induced x-ray emission spectrometry (LEXES) and one that made measurements by neutron activation analysis (NAA). The labs were asked to determine the implanted arsenic doses in three unknown samples using as a comparator Standard Reference Material 2134, with a certified dose of $7.33x10^{14}$ atoms/cm^2. The unknown samples had nominal arsenic doses of $2x10^{13}$ atoms/cm^2, $8x10^{14}$ atoms/cm^2, and $1.5x10^{16}$ atoms/cm^2, all implanted at 100 keV. The SIMS labs were requested to perform their analyses at low mass - resolving power using Cs^+ ion bombardment and $AsSi^-$ detection. Matrix signals to be monitored were Si_2^- and Si_3^-, and matrix normalization was to be done both point-by-point and to the average matrix signal. A few labs also made measurements at high mass resolving power or with O_2^+ ion bombardment and detection of As^+ and Si^+.

NIST coordinated an international round-robin study under the auspices of SIMS subcommittee SC 6 of International Organization for Standardization Technical Committee 201 on Surface Chemical Analysis.

The use of a common reference material by all laboratories resulted in much better interlaboratory agreement than was seen in the previous round robin that lacked a common comparator. The relative standard deviation among laboratories was less than 4% for the medium-dose sample, and somewhat larger for the low- and high-dose samples. There was no clear effect of the use of Si_2^- *vs.* Si_3^- matrix signals on within- or between-laboratory repeatability. The high-dose sample showed a significant difference between point-by-point and average matrix normalization because the matrix signal decreased in the vicinity of the implant peak, as previously observed. For this sample the dose from point-by-point normalization was in much closer agreement with that determined by INAA.



Measured doses and standard deviations for medium-dose As implant for SIMS labs (red dots) and LEXES labs (blue dots) with normalization to average Si_3^- matrix signal. Solid red line (AVE) is the average value for SIMS labs, the short dashed line (NOM) is requested implantation dose, and the long dashed line (NAA) is NAA-determined value.

This study demonstrates conclusively the value of NIST SRM 2134 in improving the level of agreement that can be achieved among international laboratories for the measurement of arsenic implant dose in silicon by SIMS.

Future Plans:
The results of this study will form the basis for the development of an ISO documentary standard method for depth-profiling of arsenic in silicon.

Publication:
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